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EFFECTS OF DIFFERENT DRYING RATES AND TWO INSECTICIDES
ON BEETLE ATTACKS IN FELLED DOUGLAS FIR AND WESTERN HEMLOCK

by

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SUMMARY

Second-growth Douglas fir and hemlock felled and left with the crowns intact dried out faster than those whose branches were removed. Moisture losses in trees with crowns intact were apparent shortly after felling and continued for up to six months with most of the loss occurring during warm dry weather. Sapwood moisture in some trees dropped from well over 100 per cent (oven dry weight) down to 40 per cent. Actual log weights were reduced from 10 to 33 per cent.

Ambrosia beetle attacks were significantly less in those felled trees with branches attached. The ambrosia beetle Trypodendron lineatum completely avoided trees with branches intact. Bark beetles of the genus Pseudohylesinus showed marked preference for trees with branches. Douglas fir beetle broods were much reduced in the trees with branches. Thus, it appears that the felling of second-growth trees and leaving the crowns intact for several months will not only reduce the weight of the logs, but also reduce the insect attack compared with logs left in the woods with branches removed.

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INTRODUCTION

Johnson (1961) observed that the ambrosia beetle, Trypodendron lineatum Oliver, did not attack those portions of western hemlock trees with attached branches. Attacks in logs with branches removed (limbed) averaged 26 per square foot compared to none in those portions with branches. The sapwood moisture content of the portions of the tree with branches was about half that of limbed portions.

Leaving the crown on the felled tree to hasten drying of the wood is common in many parts of the world. In Europe Beltram (1960) showed that beech trees felled in late summer and left with the crowns intact, had within a few months 20 per cent lighter wood, less checking, better appearance and made better fuel. Zahharov (1961) found that felled beech and birch left in the woods as little as 15 days with crowns intact were reduced 25 per cent in total weight over limbed and bucked trees. The rapidly drying trees produced more heat as fuel, had better buoyancy, checked less and weighed less. Boldt (1958) in the United States found that 25 days after felling sugar maple, trees with the leaves left intact had 13 per cent lower moisture content than did bucked and limbed trees. The trees with intact crowns could be used directly for charcoal; those that were felled and bucked required several additional months of air seasoning. The transpiration of water from needles of conifers is somewhat less than that from leaves of softwoods, but summer felling of conifers with the crowns intact increased the floatability of logs (Lehos, 1954). Cost was not significantly greater than that of winter logged material. Bielczyk and Eminowicz (1954) found that in Scots pine "sour-felling" (leaving the crowns on after felling) reduced the moisture content after eight weeks from 60 to 30 per cent; in oak from 86 to 60 per cent, and in beech from 65 to 45 per cent. There was no reduction in moisture in control trees that were felled and limbed. "Sour-felling" gave best results in clear cuttings as compared to partial fellings (Tonkelj, 1953). "Sour-felling" did not affect working time for limbing and cross-cutting timber in one European operation (Makkonen, 1958).

All authorities are not in agreement concerning the benefits of "sour-felling". Harzman (1955) found that felled, bucked, and limbed spruce, pine and beech dried at the same rate as those with intact crowns. Beltram (1952) indicated that leaving the crown intact above a 7-cm diameter did not materially aid the drying of spruce. Laurow (1958) reviewed the Russian, German and Polish literature concerning "sour-felling" and concluded that there are more favorable than unfavorable reports of this practice.

Vite (1961) found that in felled ponderosa pines left with the crowns intact the oleoresin pressure dropped to zero within 24 hours. If the branches were removed the oleoresin pressure

dropped slowly and measurable pressure was present for several days. Vité reported that Ips confusus readily attacked all felled trees whether they were limbed or not, but preference was exhibited for trees with branches. It is commonly recommended that logs to be used as round wood for construction, be felled and bucked in the fall and winter and left in the woods to dry, since fewer attacks by wood-boring beetles occur (Craighead, 1950). Kinghorn (1956) concluded that the lack of sapwood moisture may limit attack by Trypodendron lineatum in Douglas fir, but the presence of moisture does not necessarily attract attacks.

The purpose of this study was to determine (1) if leaving the crowns on felled second-growth hemlock and Douglas fir influenced the rate of drying of sapwood, (2) if insect attack was related to drying rate and (3) if the insecticides BHC and endosulfan would prevent ambrosia beetle attack in the down trees.

MATERIALS AND METHODS

On June 1, 1962, three western hemlocks and three Douglas firs were felled on the McDonald Tree Farm near Chehalis, Washington, and another group of three each on the Skykomish Tree Farm near Monroe, Washington. The trees were 80 to 100 years old and ranged in diameter from 18 to 30 inches. Additional sets of trees were felled at each location in September 1962 and January and April 1963. One tree of each species at each location and at each felling date, was limbed and bucked into 20-foot logs: another tree was limbed, but the bole left intact; the remaining tree was left intact. At a point midway between the butt and the first limbs, and at a point midway between the lower limbs and the top of the tree, 10-15 gram (green weight) samples of wood were removed for moisture determinations. Samples were taken with a brace and bit from the upper surface of the felled bole. Sapwood samples in Douglas fir consisted of wood from the outer xylem to a point where the white sapwood changed to the characteristic salmon color of the heartwood. In hemlock, sapwood samples were taken to a depth of two inches. Heartwood samples in both species consisted of wood from 3 to 5 inches from the outer xylem. The sample, which consisted of shavings, was placed immediately in a soil-moisture sample can and placed in a polyethylene bag for transportation to the laboratory. The samples were weighed and dried for three days at 70 degrees C². Moisture content was expressed as per cent of oven-dry

² Other commitments of the drying oven precluded using the recommended temperature of 100°C. Comparisons of 16 samples dried at 100°C with 16 samples dried at 70°C showed 1 to 3 per cent difference in moisture content, depending on the initial m. c. of the sample--those with the lower initial m. c. showing the least difference.

weight. Samples were collected only when it was not raining. Because of this limitation, samples could not be obtained each month. Following sampling, the auger hole was plugged with a cork and sealed with "tree seal".

On the assumption that starch reserves might influence beetle attack, a few chips from each oven-dried moisture sample were stained with a solution of iodine-potassium iodide to show starch grains. The relative abundance of starch was recorded in five classes--none, light, medium, heavy, very heavy--a procedure similar to that reported by Chapman et al. (1963).

In April 1963, ten-foot sections were marked off along the boles of the sample trees at Skykomish. Using a back-pack mistblower, two of these sections were sprayed with lindane, two with endosulfan (thiodan) and the rest were left unsprayed. All treatments were assigned at random. The insecticide formulations were made from emulsifiable concentrates at the rate of $1\frac{1}{2}$ pounds of active ingredient per 100 gallons of water. Log sections were sprayed until run-off occurred. Most of the spraying was completed before a light rain commenced. It rained almost every day from the time of spraying until the first attacks occurred a month later.

In June 1963, a section of bark five feet long was removed from around the log at the center of each 10-foot section and the number of insect attacks were tallied. For analysis the number of insects was adjusted to a standard section size of 16-inch diameter 5 feet long (Ca. 21 sq. ft.).

RESULTS

Moisture content of wood

The moisture contents of the sapwood of the study trees immediately after felling are given in Table 1. There was no significant difference among trees of the same species felled at the same time. There was a highly significant difference (1 per cent level of probability) between tree species, western hemlock wood being the wetter. Wood taken nearer the top of the tree had a higher moisture content. Trees felled in January had a significantly (1 per cent level) higher moisture content than those felled at other times of the year. Trees at McDonald had a higher moisture content than those at Skykomish (5 per cent level).

The progression of moisture loss or gain for each individual tree is given in Figures 1 through 7. The effect branches have on drying is obvious in most cases. It is interesting to note that the sapwood moisture increased in many of the trees during the wet winter and that the increase was greater in limbed trees than in those with branches. The moisture

Table 1. Moisture content of sapwood of second-growth Douglas fir and western hemlock at time of felling. (Per cent of oven-dry weight).

Tree Farm	Date of felling	Douglas fir			Hemlock		
		Butt	Top	Ave.	Butt	Top	Ave.
Skykomish	June 1962	73.6	88.0	80.8	117.1	119.3	118.2
	Sept. 1962	72.7	77.6	75.2	94.8	99.8	97.3
	Jan. 1963	86.8	97.0	91.9	149.6	138.3	144.0
	April 1963	86.8	90.1	88.5	102.0	95.7	98.9
	Average	80.0	88.2	84.1	115.9	113.3	99.33
McDonald	June	72.9	97.7	85.3	113.7	101.4	107.5
	Sept.	99.4	108.6	104.0	95.9	122.2	109.1
	Jan.	100.3	111.6	106.0	127.3	142.4	134.4
	April	89.9	104.3	97.1	104.8	136.9	120.9
	Average	90.6	105.6	98.1	110.2	125.7	108.2
Average		85.31	96.85	91.09	113.04	119.50	103.68

Figures 1-7. Moisture contents by month for limbed, limbed and bucked and unlimbed Douglas fir and hemlock trees.

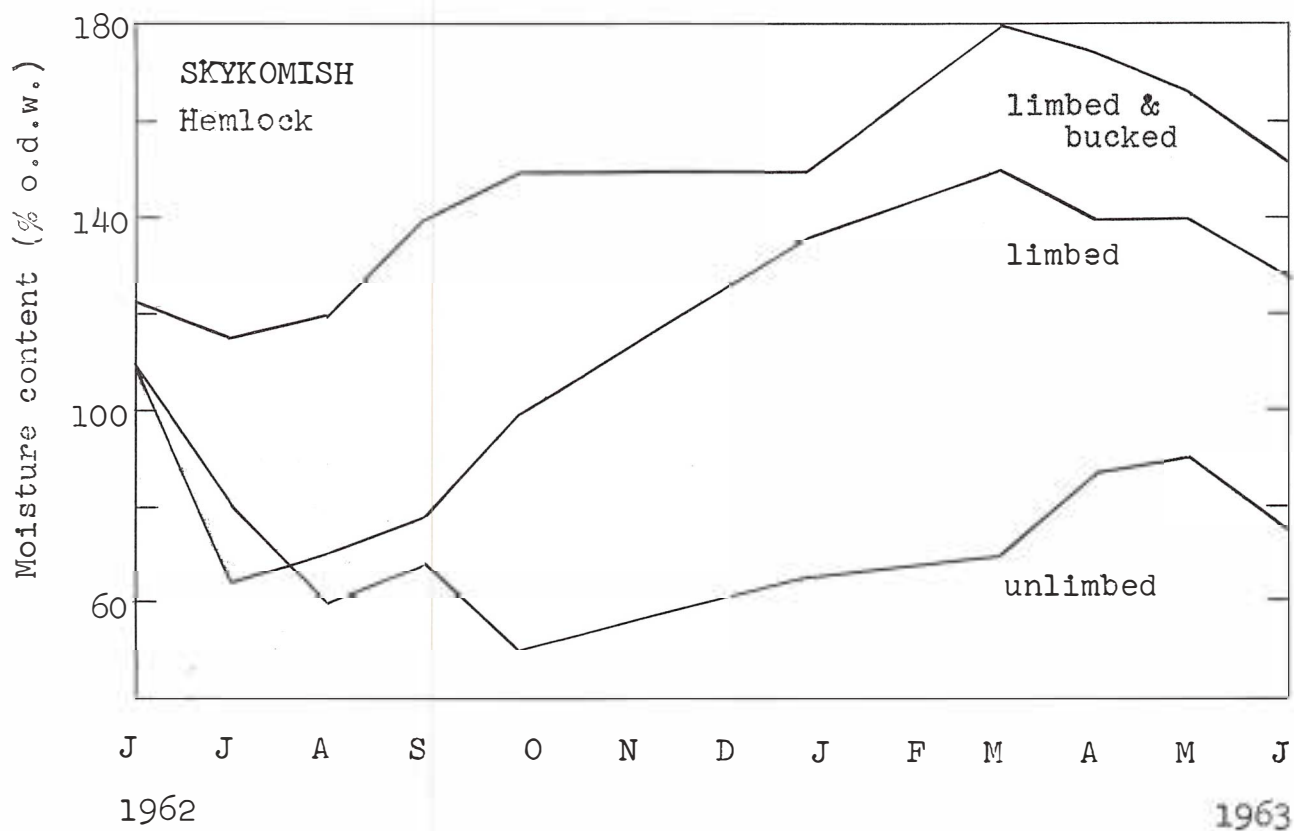
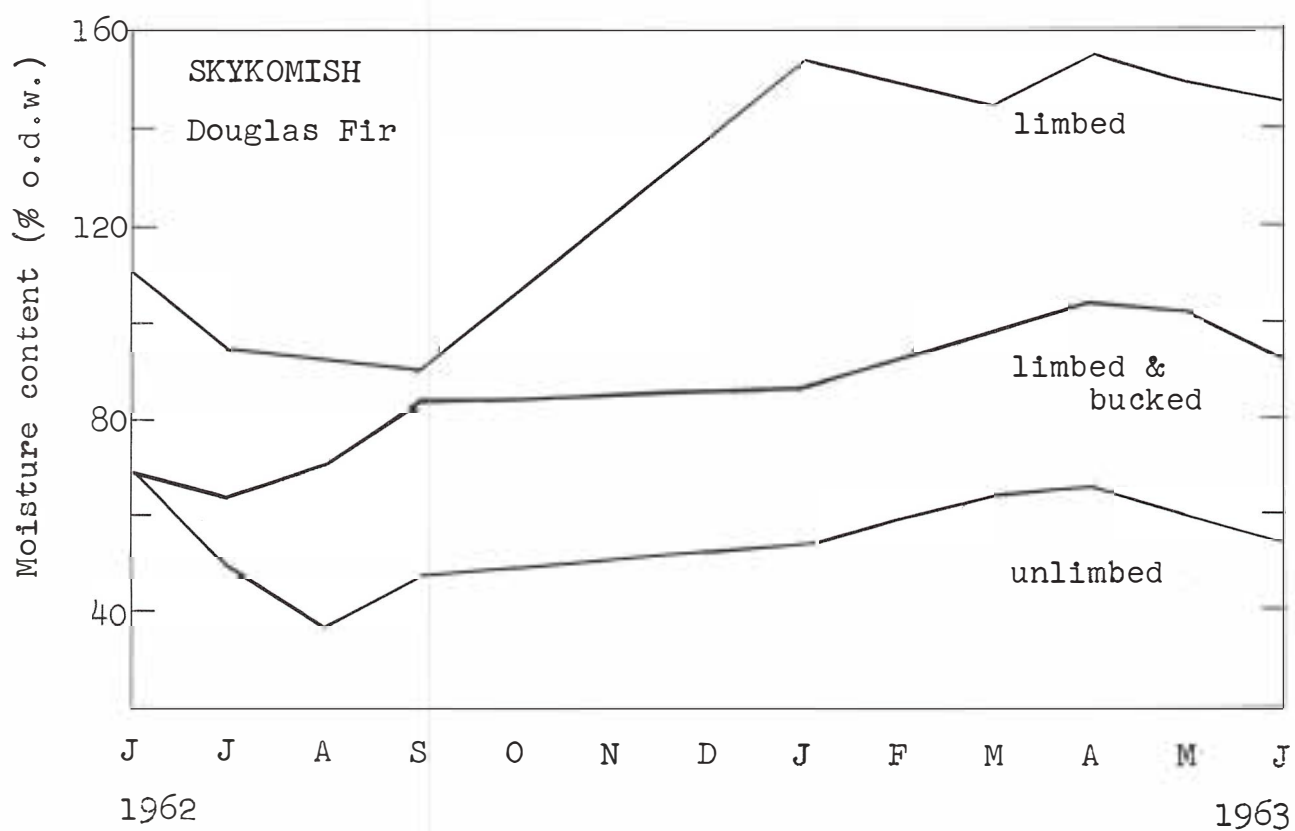


Fig. 1-Skykomish Tree Farm - Douglas Fir and Hemlock, Felled June 1962



Fig. 2 - McDonald Tree Farm - Douglas Fir - Felled June 1962

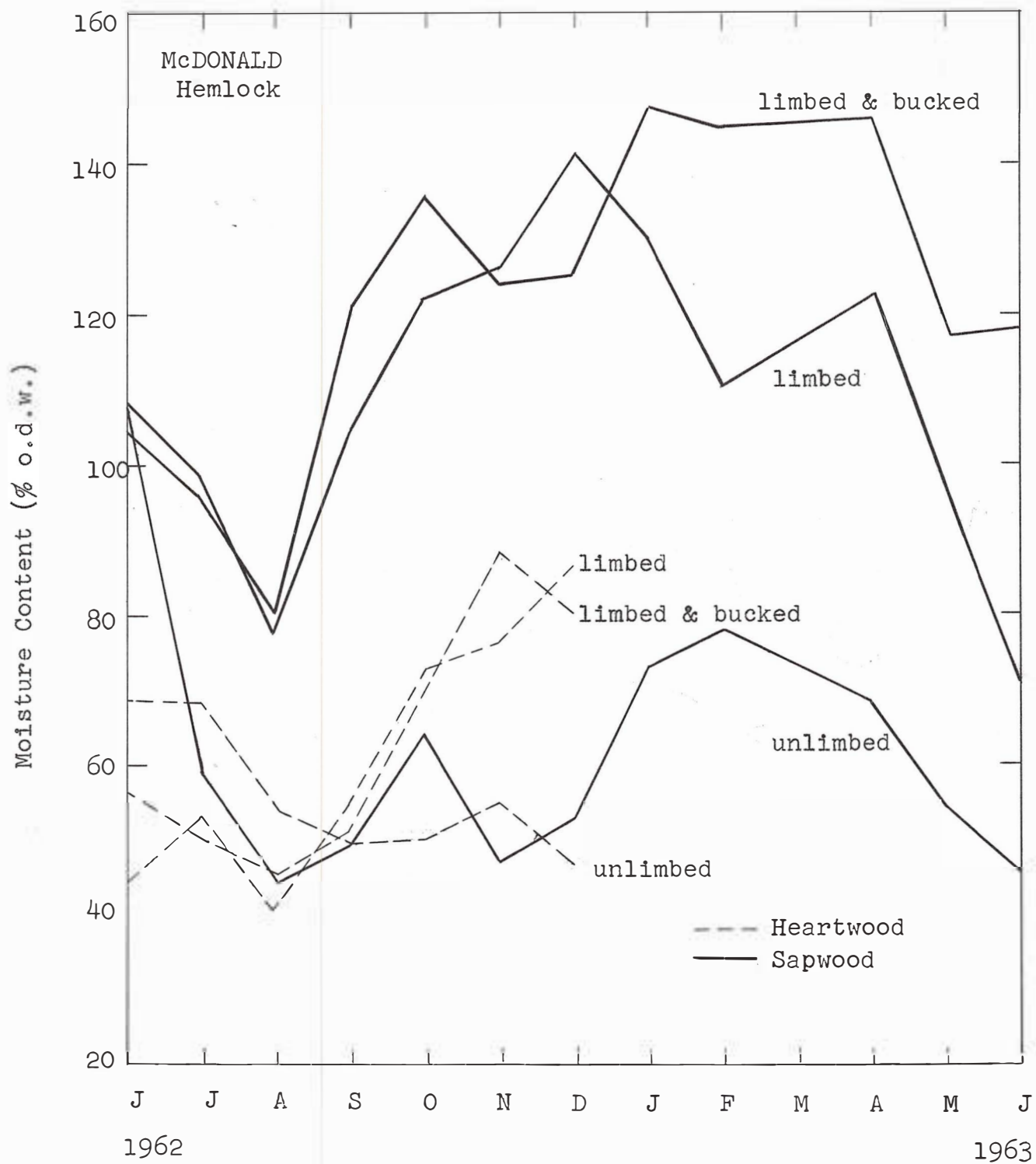


Fig. 3 - McDonald Tree Farm - Hemlock - Felled June 1962

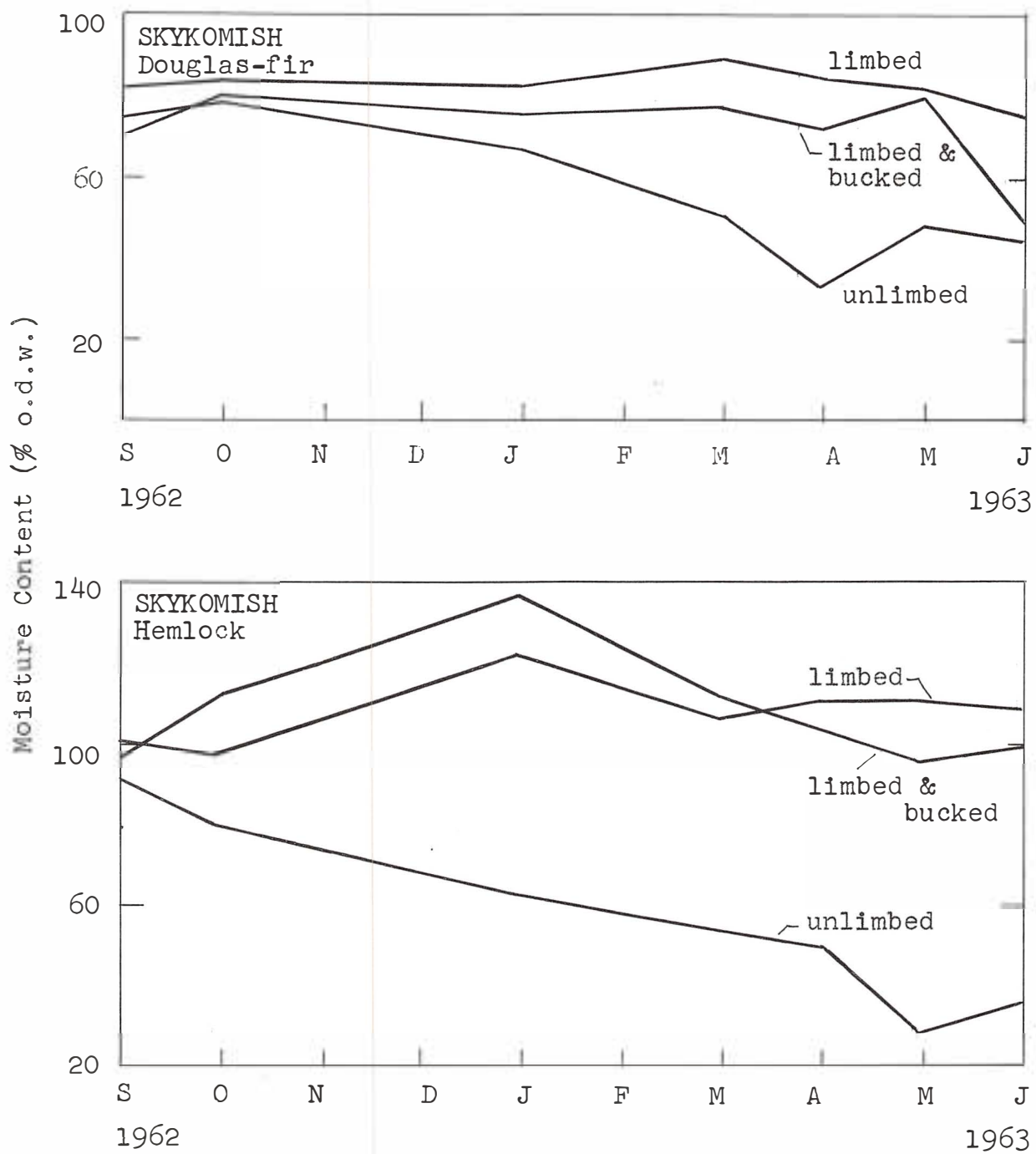


Fig. 4 - Skykomish Tree Farm - Douglas Fir and Hemlock -
Felled September 1962

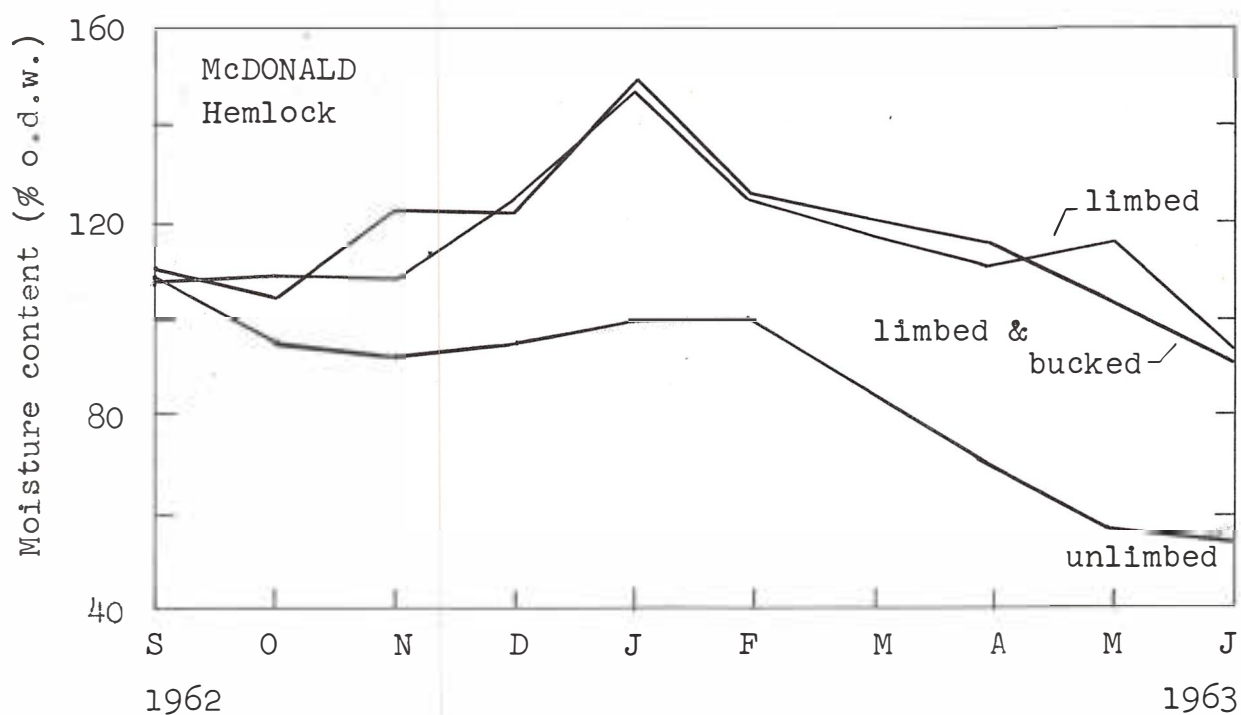
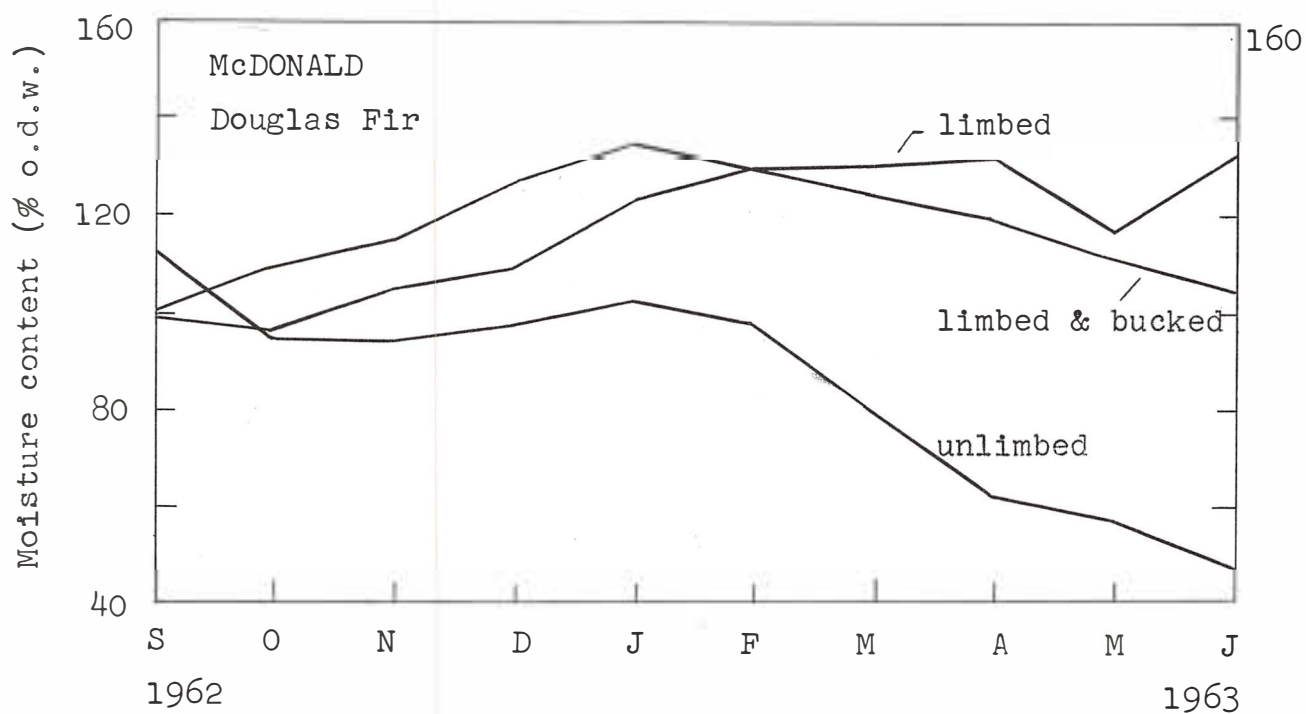


Fig. 5 - McDonald Tree Farm - Douglas Fir and Hemlock -
Felled September 1962

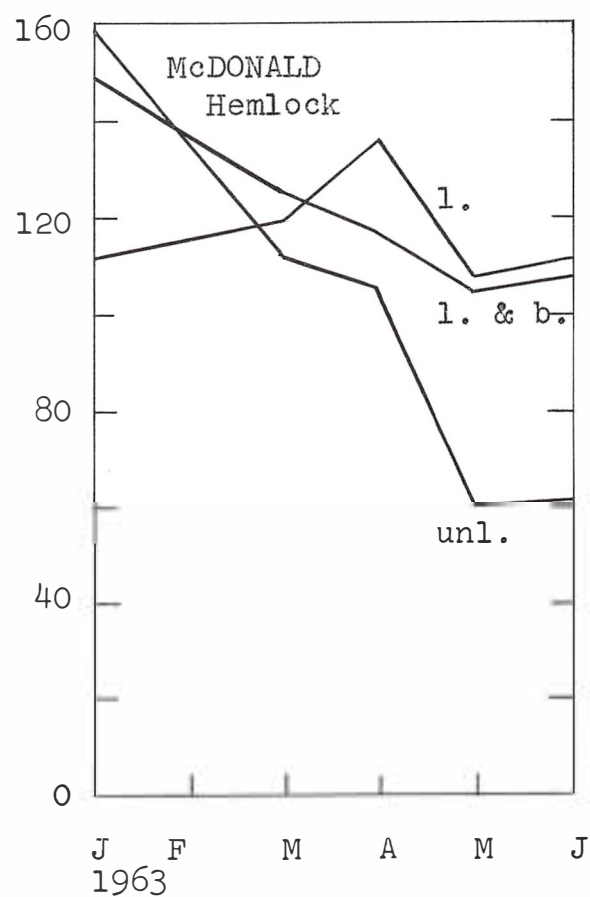
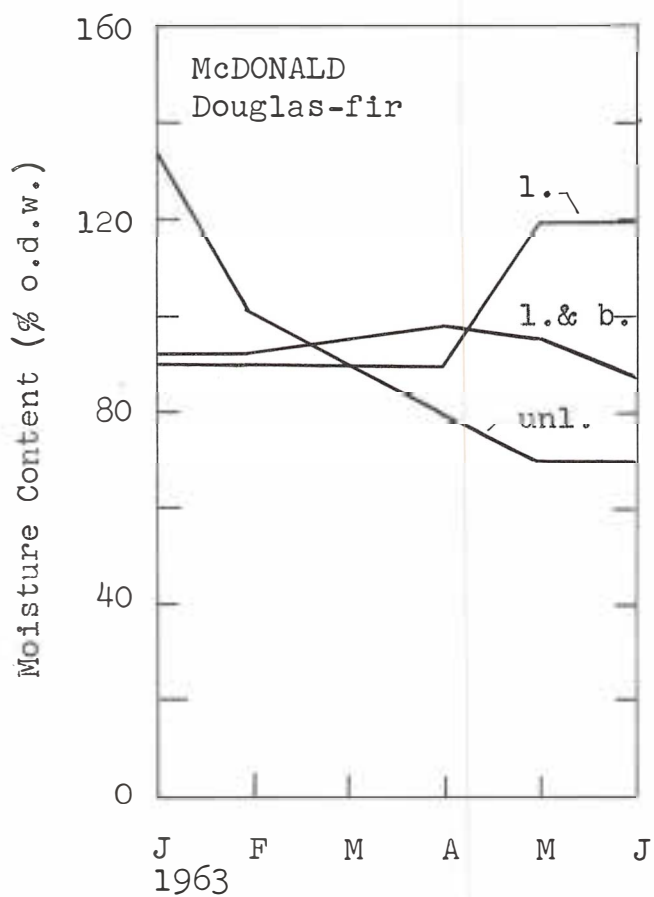
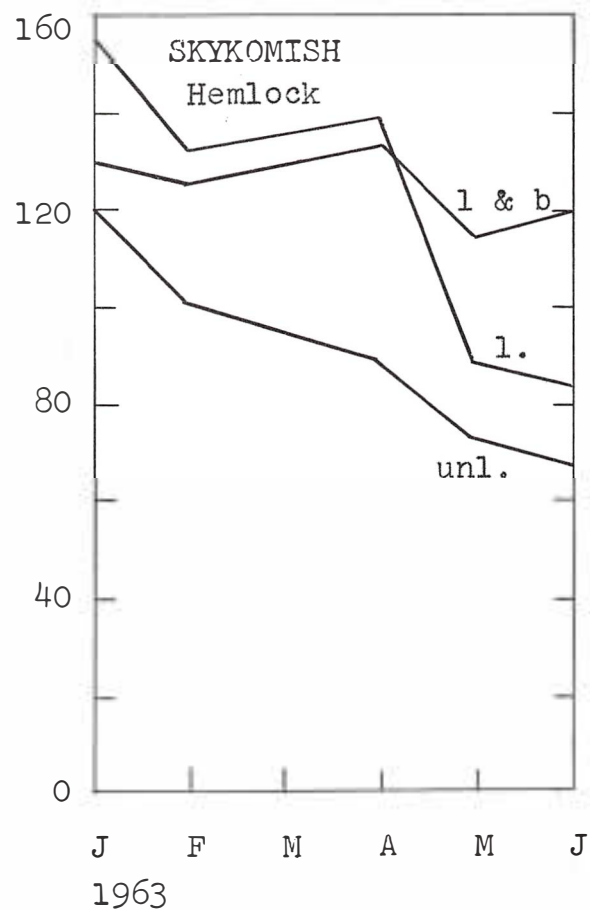
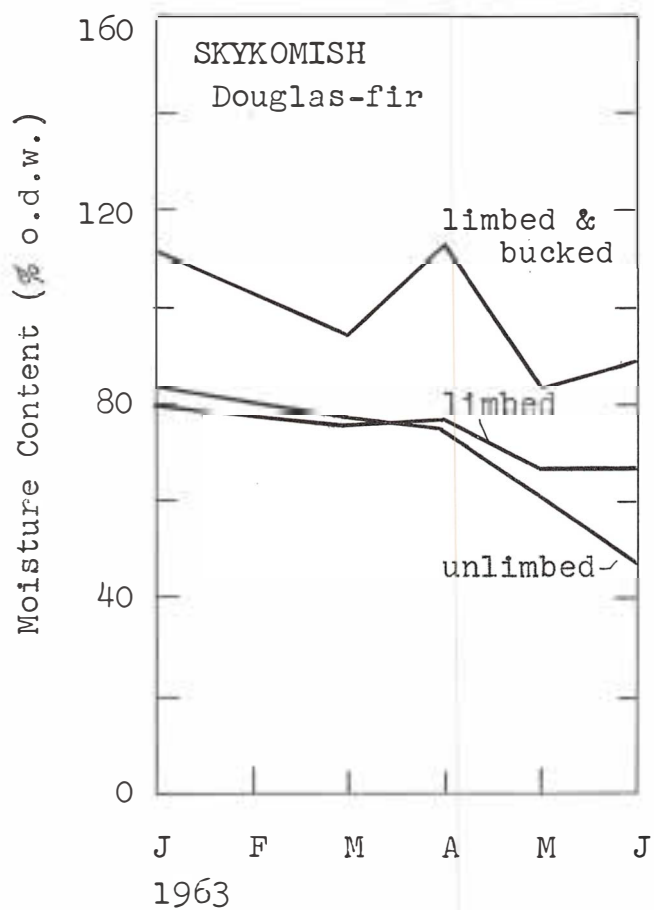


Fig. 6 - Skykomish and McDonald Tree Farms - Douglas Fir and Hemlock - Felled January 1963

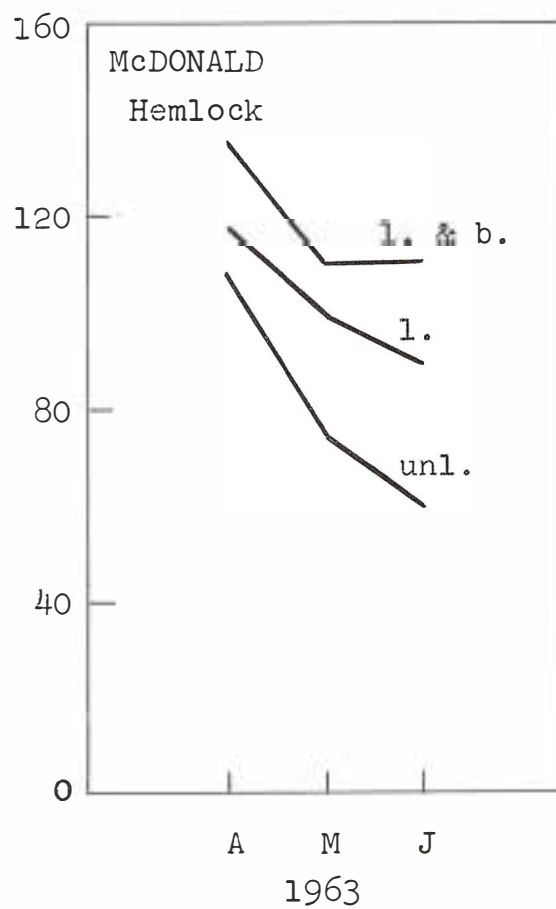
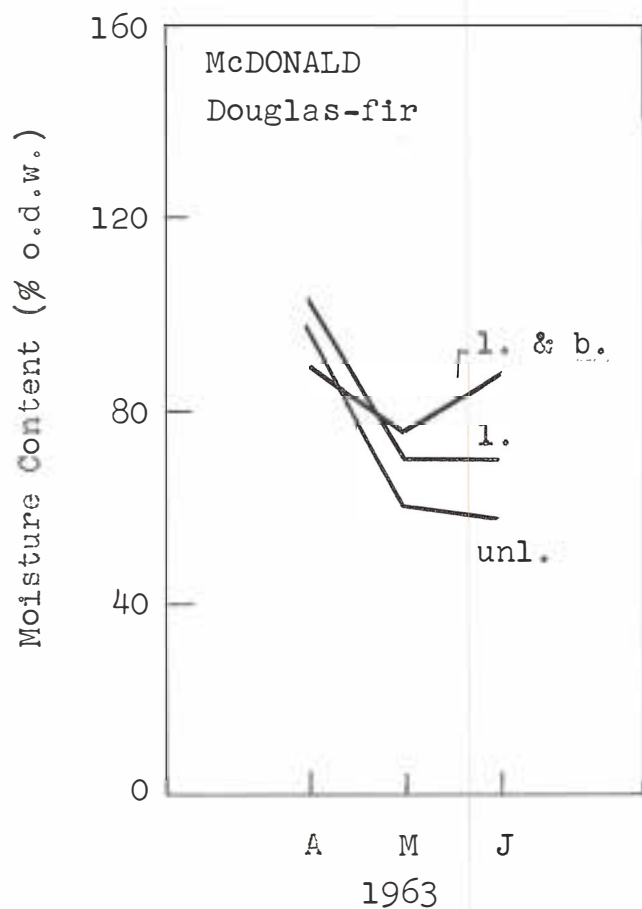
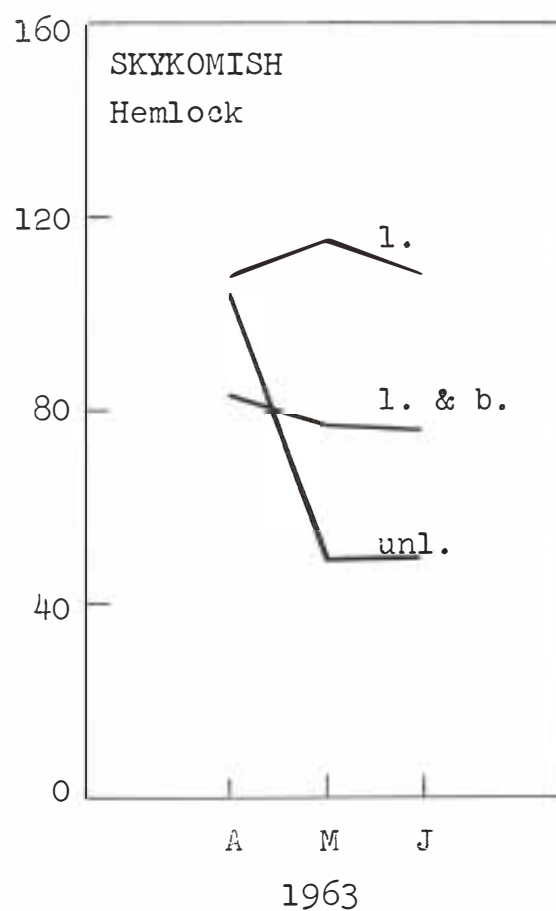
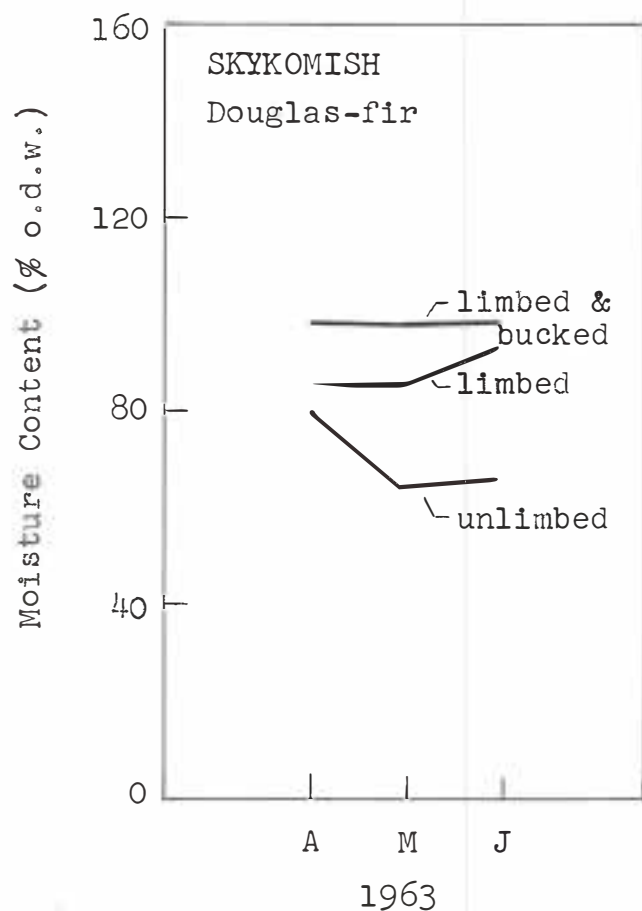


Fig. 7 - Skykomish and McDonald Tree Farms - Douglas Fir and Hemlock - Felled April 1963

contents of the heartwood for trees felled in June 1962 at McDonald are plotted in Figures 3 and 4. The heartwood of Douglas fir showed a slight increase with increasing sapwood moisture in all trees. In hemlock, the heartwood followed closely the pattern of the sapwood. Hemlock heartwood in freshly felled trees averaged 55.5 per cent moisture; Douglas fir averaged 33.0 per cent. Heartwood sampling was discontinued after December.

Statistical analyses of the moisture content data were made at the end of each three-month period. Limbing treatment had a highly significant (1 per cent level) influence in all analyses. Date of felling, tree species and tree location (tree farm) were significant in most cases. There were significant interactions between limbing treatments and date of felling, indicating that only limbed trees were lower in moisture than newly felled trees. Moisture content at the two sampling positions was not significantly different after the trees were on the ground for three months or longer.

After trees were felled in June, the visible starch grains disappeared within four months from all except unlimbed trees. Even after eight months there was a trace of starch in unlimbed trees. Trees felled in the winter and spring all retained some visible starch through June 1963, but unlimbed trees had greater amounts. Trees felled in January and April appeared to have more starch than those felled at other times of the year.

Insect Attack

The number of insect attacks per adjusted 5-foot section of bole is given in Tables 2 and 3. At Skykomish no Trypodendron attacked any of the logs for some unexplained reason. Ambrosia beetles of the genus Gnathotrichus were the most abundant insect. There were significantly fewer Gnathotrichus in unlimbed trees except for those trees felled in June 1962. Trees felled at this time were attacked soon after felling and before there was significant reduction in sapwood moisture. Trypodendron attacks at McDonald were concentrated in limbed, and limbed and bucked Douglas fir felled in September 1962. No Trypodendron occurred in any unlimbed trees. No Trypodendron attacked any of the trees felled in June 1962 or in April 1963. The 1962 attack season for Trypodendron was essentially over by the time the June trees were felled. Trypodendron avoids freshly felled trees. This accounts for the lack of attacks in trees felled in April 1963.

There was no difference in Douglas fir beetle attacks in regard to limbing. As was the case with the ambrosia beetles, the trees felled in June 1962 were attacked by the 1962

Table 2. Average number of insects per 5-foot section of bole (averages computed from two sections) of felled Douglas fir and western hemlock on Skykomish Tree Farm¹.

Date of felling	Limbing treatment	Ambrosia beetles	Bark beetles	
		Gnath.	Dend.	Pseudo.
June 1962 Douglas fir	Limbed	77	15	0
	Limbed and bucked	77	21	0
	Unlimbed	16	15	4
	Average	56.7	17.0	1.3
Hemlock	Limbed	89	—	18
	Limbed and bucked	131	—	12
	Unlimbed	199	—	23
	Average	139.7	—	17.7
Sept. 1962 Douglas fir	Limbed	7	4	0
	Limbed and bucked	59	1	0
	Unlimbed	0	3	38
	Average	22	2.7	12.7
Hemlock	Limbed	53	—	0
	Limbed and bucked	54	—	0
	Unlimbed	3	—	0
	Average	36.7	—	0
Jan. 1963 Douglas fir	Limbed	0	2	0
	Limbed and bucked	0	6	0
	Unlimbed	2	7	61
	Average	0.7	5.0	20.3
Hemlock	Limbed	56	—	0
	Limbed and bucked	120	—	0
	Unlimbed	20	—	0
	Average	65.3	—	0
Apr. 1963 Douglas fir	Limbed	0	5	0
	Limbed and bucked	0	16	0
	Unlimbed	0	8	0
	Average	0	9.7	0
Hemlock	Limbed	30	—	0
	Limbed and bucked	13	—	0
	Unlimbed	0	—	0
	Average	14.3	—	0

¹ Abbreviations: Gnathotricus sp., Dendroctonus pseudotsugae, Pseudohylesinus nebulosus (in Douglas fir) and P. sp. (in hemlock).

Table 3. Average number of insects per 5-foot section of bole (averages computed from two 5-foot sections) of felled Douglas fir and western hemlock on McDonald Tree Farm.¹

Date of felling	Limbing treatment	<u>Ambrosia beetles</u>		<u>Bark beetles</u>	
		Tryp.	Gnath.	Dend.	Pseudo.
June 1962 Douglas fir	Limbed	0	11	27	0
	Limbed and bucked	0	25	36	0
	Unlimbed	0	96	21	13
	Average	0	44.0	28.0	4.3
	Limbed	0	40	—	5
	Limbed and bucked	0	23	—	28
	Unlimbed	0	10	—	41
	Average	0	24.3	—	24.7
Sept. 1962 Douglas fir	Limbed	166	0	5	0
	Limbed and bucked	256	4	11	0
	Unlimbed	0	0	5	44
	Average	140.7	1.3	7.0	14.7
	Limbed	10	0	—	0
	Limbed and bucked	9	0	—	0
	Unlimbed	0	0	—	6
	Average	3.3	0	—	2.0
Jan. 1963 Douglas fir	Limbed	8	0	18	0
	Limbed and bucked	5	1	14	0
	Unlimbed	0	3	6	40
	Average	4.3	1.3	12.7	13.3
	Limbed	0	2	—	14
	Limbed and bucked	35	2	—	1
	Unlimbed	0	4	—	16
	Average	11.7	2.7	—	10.3
Apr. 1963 Douglas fir	Limbed	0	0	10	0
	Limbed and bucked	0	0	11	0
	Unlimbed	0	0	3	0
	Average	0	0	8.0	0
	Limbed	0	0	—	0
	Limbed and bucked	0	0	—	0
	Unlimbed	0	0	—	0
	Average	0	0	—	0

¹ Abbreviations: Trypodendron lineatum, Gnathotricus sp., Dendroctonus pseudotsugae, Pseudohylesinus nebulosus (in Douglas fir) and P. sp. (in hemlock).

flight of beetles, whereas the remainder were not attacked until the spring of 1963. The higher number in the June trees, therefore, reflects year-to-year variation rather than a difference due to date of felling. Trees felled in June 1962 were not attacked by Douglas fir beetles from the 1963 spring flight.

Brood survival of Douglas fir beetles in Douglas fir felled in June 1962 varied significantly by branching treatment. At both McDonald and Skykomish the brood survival in unlimbed trees was less than 10 per cent of potential (potential here equaling the number of larval galleries started). In those limbed trees the brood survival was nearly 50 per cent.

A strong preference was exhibited by Pseudohylesinus spp. at both tree farms. Only felled Douglas fir with intact crowns were attacked by P. nebulosus. Freshly felled trees were avoided completely by this insect. The Pseudohylesinus species in hemlock showed the same preference for unlimbed trees, but not to the same degree. The effect of the two insecticides is apparent from the data in Table 4. There were practically no attacks on treated sections; adjoining untreated sections contained up to 100 ambrosia beetle attacks. These results are similar to findings of Kinghorn (1961) and Allen and Rudinsky (1959).

DISCUSSION

The use of an auger to collect samples probably results in lower moisture contents than would be obtained by other means. Huckenpahler (1936) found that moisture content of shortleaf pine obtained from auger samples averaged about 20 per cent less than whole block measurements, but the correlation between the two measurements was high.

Since all samples were taken from the top of the fallen bole--the position of greatest drying--it was necessary to check other sampling positions to determine differences in moisture content. At Skykomish, at the last period of sampling, sapwood samples from the shaded side of the bole were taken in addition to the top samples. The moisture content on the side was greater than that on the top. (Table 5). The difference between the side and top samples was less for unlimbed trees than for limbed trees.

The most striking evidence for the drying ability of attached branches came from sampling the intact tops severed from the bucked trees. The moisture content of wood with branches attached averaged 33.3 per cent; that from the limbed bole only a few feet away averaged 98.2 per cent moisture.

The moisture loss in unlimbed trees may be a significant consideration in reducing the weight of trees and therefore,

Table 4. Average number of insect attacks per 5-foot section of bole following treatment with BHC and endosulfan in comparison with untreated sections.

Insect	Treatment						Ave.
	Control		BHC		Endosulfan		
	D.f.	Hemlock	D.f.	Hemlock	D.f.	Hemlock	
Gnathotrachus	7.4 ¹	38.4	0	0.1	0	0	7.7
Douglas-fir beetle	5.4	---	0.6	---	0	---	2.0
Pseudohylesinus	11.0	3.0	0	0	0.2	0	2.4
Average	7.9	20.7	0.2	0.05	0.07	0.0	4.3

¹ Average of attacks on 18 5-foot sections.

Table 5. Average moisture content of all trees by limbing treatment and position of sample. (Skykomish trees only--sampling in June, 1963).

Limbing treatment	Butt position			Top position			Ave. diff.
	Top ¹	Side ²	Diff.	Top	Side	Diff.	
Unlimbed	56.1	64.8	8.7	52.6	56.0	3.4	6.1
Limbed and bucked	97.8	115.7	17.9	91.5	102.6	11.1	14.5
Limbed	98.4	108.5	10.1	113.7	124.8	11.1	10.6
Average	84.1	96.3	12.2	85.9	94.4	8.5	10.4

¹ Usual point of sample on top of fallen bole.

² Sample from shady side of bole.

the logging costs. For example, the moisture content of the unlimbed Douglas fir in Figure 6A dropped from about 110 per cent to 48 per cent. The loss in weight per cubic foot was about 16 pounds³. Assuming a 16-foot log with a mid-diameter of 10 inches and 2-inch-thick sapwood, the per cent reduction in weight of the log is about 23 per cent. A 20-inch (mid-diameter) log of the same length and sapwood thickness would be reduced 14 per cent in weight assuming the same moisture loss.

The unlimbed hemlock tree in Figure 7D lost sapwood moisture from 160 to 60 per cent with a corresponding weight loss of about 25 pounds per cubic foot. Assuming a log of 16 feet with mid-diameter of 10 inches, but with 3-inch thick sapwood we could expect nearly 33 per cent reduction in total weight of the log. Assuming that forty 10-inch hemlock logs could be hauled on a truck, the saving in weight resulting from air seasoning with limbs intact amounts to more than 7,000 pounds per load.

It would appear that it might be economical to leave small trees, such as thinnings in young stands, intact overwinter in order to dry out prior to logging. Felling could be done during the winter when the roads are too muddy for logging. In addition it appears that trees felled in the fall, winter and spring and left with branches intact would have very few or no wood-boring beetles to cause degrade.

Chapman et al. (1963) were unable to find a direct relationship between starch content of Douglas fir and hemlock logs and attacks by the ambrosia beetle *Trypodendron*. In general they found that this insect attacked logs with low starch content, but many similar logs were unattacked. They suggest that the physiological condition of the tree at the time of felling may be more important than the change in condition after felling. The starch content in recently felled trees is, however, associated with the moisture content of the wood. Wilson (1933) demonstrated that if wood were rapidly dried, the starch content remained high, whereas, if allowed to season slowly the starch gradually disappeared. Chapman et al. (1963) noted that the starch content in bucked logs remained high near the ends--a phenomenon possibly explained by the rate of drying. The high heat value claimed for trees that were "sour-felled" is probably due to high starch or other polysaccharide content.

Although several workers have demonstrated a relationship between starch content of dry wood and attacks by powder-post

³ Data necessary for calculations taken from Wood Handbook, U. S. D. A. Handbook No. 72. 1955. 528 pp.

beetles, there is little clear-cut evidence of the role of starch or other plant metabolites in the attack of freshly felled trees. Such information would be of value in planning felling operations to minimize losses to wood-boring insects.

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